1944

The Grasshopper Mite : Eutronbidium trigonum (Hermann) : An Important Enemy of Grasshoppers

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Technical Bulletin 3 May, 1944

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Table of Contents

NOMENCLATURE AND SYNONYMY ... 3
LIFE CYCLE AND SEASONAL HISTORY ... 5
ADULT MITES ... 8
- Description ... 8
- Oviposition and Feeding in Spring ... 10

EGGS OF GRASSHOPPER MITE ... 11
- Description of Eggs ... 11
- Average Number Laid ... 12
- Incubation of Eggs ... 13

LARVAL STAGE OF GRASSHOPPER MITE ... 15
- Description of Recently Hatched Larva ... 15
- Behavior of Larval Mites Shortly After Hatching ... 16
- Larva's Attack on Grasshoppers ... 16
- Seasonal Abundance of Mites in Larval Stage ... 21
- Detachment of Larvae from Grasshoppers ... 21
- Description of Engorged Active Larva Recently Dropped from a Grasshopper ... 23
- Engorged Inactive Larva ... 24
- Larvae Do Not Attack Human Beings ... 25

PRENYMPHAL PUPA ... 25
- Description ... 25
- Length of Prenymphal Pupal Period ... 26
- Seasonal Abundance ... 27

NYMPH OF GRASSHOPPER MITE ... 27
- Emergence of Nymph from Prenymphal Pupa ... 27
- Description of Nymph Before Feeding ... 27
- Duration of Nymphal Stage ... 28
- Seasonal Abundance ... 28
- Food of Nymphal and Adult Mites ... 28
- Technique of Feeding and Rearing Nymphs ... 29
- Ability of Grasshopper Eggs Used as Food to Hatch ... 30
- Transformation of Active Engorged Nymph Into Inactive Engorged Nymph ... 30

PREIMAGINAL PUPA ... 32
- Description ... 32
- Period as Inactive Engorged Nymph and Prenymphal Pupa ... 33
- Seasonal Abundance ... 33

ADULT MITES ... 33
- Emergence from Preimaginal Pupa ... 33
- Seasonal Abundance ... 33
- Abundance of Nymphal and Adult Mites in or on Soil ... 34
- Number of Mites Found Within Grasshopper Egg Pods ... 34

DEATH FEIGNING ... 34
SUMMARY ... 34
LITERATURE CITED ... 36

The Grasshopper Mite

Eutrombidium trigonum (Hermann)

An Important Enemy of Grasshoppers

By H. C. SEVERIN, Entomologist[1]

Grasshopper damage is an important problem in large sections of the United States. The results of extensive damage in past years affected agricultural and horticultural pursuits as well as other occupations. One of the important biological checks to grasshoppers in this country is the grasshopper mite, *Eutrombidium trigonum* (Hermann), for in its larval stage it is parasitic on grasshoppers and in its nymphal and adult stages it preys on grasshopper eggs.

Although the pioneer work of Riley (10) in 1878 and the later work of Howard (6) in 1918 gives much valuable information concerning the life cycle, seasonal history, biology, and economic importance of the mite, a thorough study of it in the light of present information and under present conditions was urgently needed.[2] This bulletin gives the results of such a study.

COMMON NAMES

The grasshopper mite is known by a comparatively small number of common names, some of the more frequently used being the following: locust or grasshopper mite, red mite of grasshopper or locust, locust or grasshopper tick, silky red mite of grasshopper or locust, red bug of grasshopper or locust, red spider of grasshopper or locust, chigger of grasshopper or locust, and louse of grasshopper or locust.

DISTRIBUTION OF MITES

The grasshopper mite is generally distributed over South Dakota. It is found in the Black Hills in the western part of South Dakota, in the Sand Hills in Todd, Bennett, and Shannon counties, in the Badlands, over the Pierre shale soils occupying much of the land area west of the Missouri river, and throughout the glaciated area east of the Missouri river.

Apparently the mite is not greatly influenced in its distribution by even large variations in rainfall or soil moisture, for it may occur in wet bottom lands as well as on dry hillsides in the same or in different areas in the State. Flooding of land for several weeks, however, is damaging to the mites and reduces their numbers materially. Prolonged drought, during which the soil becomes exceedingly dry, also destroys many of the mites in the late larval, pupal, nymphal, and adult stages.

NOMENCLATURE AND SYNONYMY

In 1804 J. F. Hermann (5) described and named a mite, *Trombidium trigonum*. In 1821 Say (11) named two mites *Trombidium scabrum* and *Trombidium sericeum*. At the same time he described the two mites, though inadequately.

[1] The writer's thanks are due G. B. Spawn of the South Dakota Station and George Gilbertson of the South Dakota Extension Service for preparing the drawings used in this publication.

[2] Numbers in parentheses refer to Literature Cited, p. 36.

In the first volume of the Practical Entomologist is a copy of a letter which Walsh (13) wrote Walter Ridell of Canada West. This letter states:

"The small red mites, about the size of a pin, which you find attached in great numbers to the wings of grasshoppers, have long been known to me: but so far as I am aware, they have never been named or described. They are allied to the genus *Uropoda,* a species of which attaches by the tail to the bodies of certain dung-beetles in Europe, but differ in attaching themselves, not by the tail but by the head, and in the front pair of legs being not only exceedingly small, but so small that I cannot distinguish them at all, so that the animal is apparently six-legged, like a true louse. Yet the general characters are those of the mites. Most mites, indeed, when in the larva or immature state, have only six legs, but all that I have examined of your species are apparently in the perfect state. Not improbably it may belong to Latreille's genus *Astoma,* a European species of which is said to be parasitic upon flies and other insects, and which has only six legs. In that case it may be called *Astoma locustarum,* as it is distinct from the European species by the body not being at all constricted in the middle."

Apparently this is the first published record of the presence of the grasshopper mite in North America. Evidently Walsh believed that the larval mites which he found attached to grasshoppers were adult, but still he did not seem to be entirely convinced about this.

In 1872 LeBaron (7) named the larval mites, *Atoma gryllaria* but stated that the name *Astoma gryllaria* would have been more appropriate were it not that the name *Astoma* was already appropriated for a genus of radiate animals.

In his seventh annual report on the Noxious, Beneficial and Other Insects of the State of Missouri, published in 1877, Riley (9) reported that in 1868 Uriah Bruner of Omaha, Nebraska, had sent him the rocky-mountain locust infested with the grasshopper or locust mite. The following year the mite was reported from Oregon, Missouri, and Kansas.

In the same seventh annual report Riley wrote that in May, 1874, Professor C. E. Bessey sent him a pale red mite from Iowa together with an account of its destructive work on the eggs of the rocky-mountain locust. In the same year numerous encouraging reports were published in newspapers and farm journals to the effect that the mites were destroying immense numbers of locust eggs.

In his seventh annual report, Riley (9) recognized the larval mites which attacked the rocky-mountain locust as the same species that LeBaron described as *Atoma gryllaria* in 1872 and which Walsh named *Astoma locustarum* in 1866. In his sixth annual report Riley (8) wrote that "The genera *Astoma, Leptis, Caris, Myobia,* etc., are now known to be but larval forms, some of them commonly met with as such but not yet connected with the more perfect and mature forms." A year later in his seventh report Riley wrote:

"As remarked in my last report the genus *Astoma* and probably most other six-legged genera, are only larval or immature forms of some other mites; and this very locust mite may be the larva of the Silky mite previously described, for ought we know to the contrary—there is so much to learn yet of the mites. Indeed Hermann, and some other arachnologists have actually referred *Astoma* to *Trombidium*."

In his seventh report Riley identified the locust mite as *Trombidium sericeum* Say but wrote that he could not be certain of his determination because Say's description was too brief. In the first annual report of the U. S. Entomological Commission for the year 1877 relating to the rocky-mountain locust (10) there appeared an account by Riley of the life cycle of the grasshopper mite. While the account of the life cycle is by no means correct, it at least proved definitely that a six-legged larva which is parasitic on the body or appendages of grasshoppers is the larval form of an adult mite that feeds upon the eggs of grasshoppers. In this same first report of the United States Entomological Commission, Riley named the locust mite *Trombidium locustarum* and published a description of the adult

mites, the eggs, the newly hatched larvae, the engorged larvae, and the prenymphal pupae.

In 1894 Banks (1) placed the mite in the genus *Ottonia* and called it *Ottonia locustarum* Riley. In 1909 Verdun (12) erected the subgenus *Eutrombidium* and named the grasshopper mite *Trombidium (Eutrombidium) trigonum* Hermann. By 1910 the genus *Trombidium* had been divided into many genera and subgenera, mostly by Berlese (2). Berlese placed this grasshopper mite in the genus *Eutrombidium* and called it *Eutrombidium locustarum* (Walsh). In 1909 Ewing (3) placed the locust mite in the genus *Microtrombidium* and discussed it under the name *Microtrombidium locustarum* (Walsh).

In 1912 Ewing (4) sent an adult locust mite to Berlese who determined it as *Eutrombidium locustarum* (Walsh). Berlese in his work "Trombidiidae" published in 1912 does not consider *Eutrombidium locustarum* (Walsh) synonymous with *Eutrombidium trigonum* (Hermann), but separates the two species by a number of distinguishing characters.

In 1912 Ewing (4) sent a larva of the locust mite to Dr. Oudemans who identified it as the European *Eutrombidium trigonum* (Hermann) described by Herman in 1804.

If the identification and conclusions of Dr. Oudemans are accepted, then the valid name of the common grasshopper mite is *Eutrombidium trigonum* (Hermann). The following names must then be regarded as synonyms:

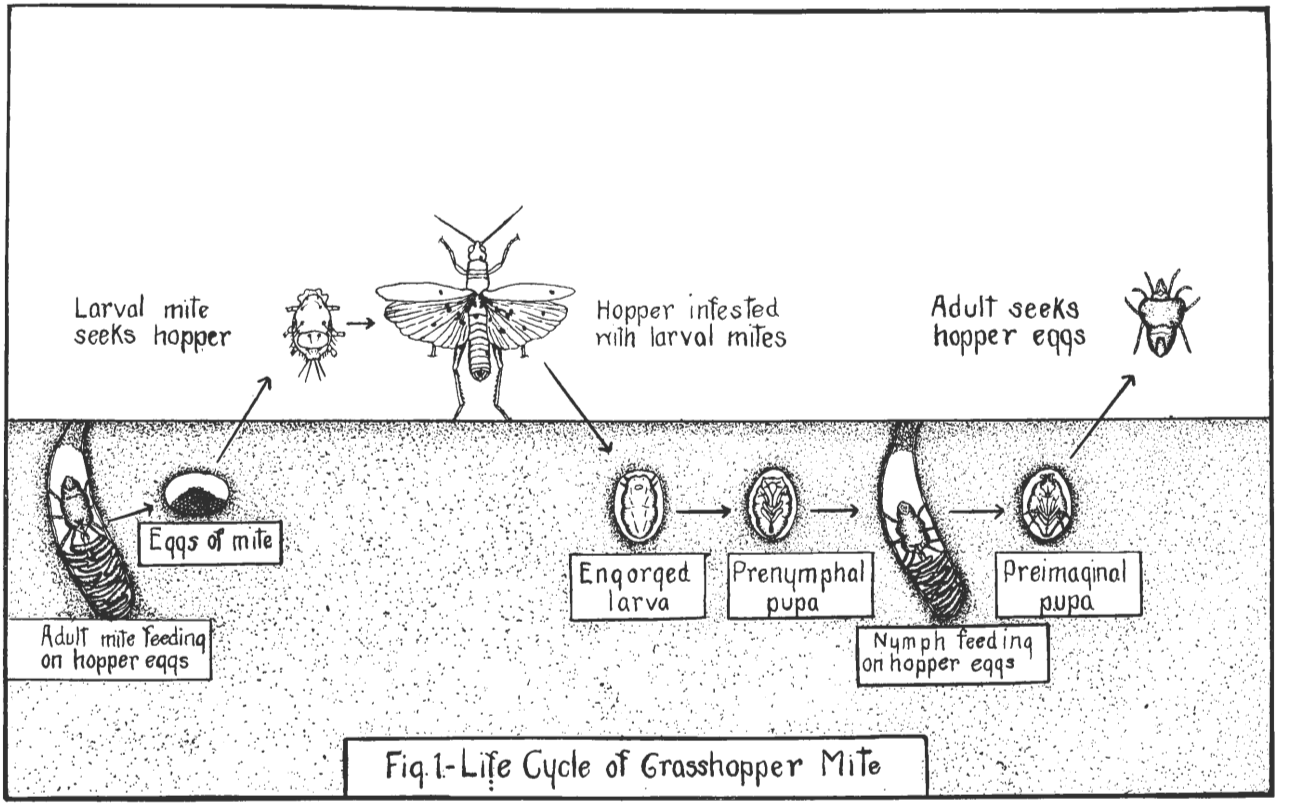
Trombidium sericeum Say
Astoma locustarum Walsh
Atoma gryllaria LeBaron
Trombidium locustarum (Riley)
Ottonia locustarum (Riley)
Microtrombidium locustarum (Walsh)
Eutrombidium locustarum (Walsh)

Verdun in 1909 declared as synonyms the following names which were used to designate certain larval mites: *Trombidium holosericeum* Berlese and *Allotrombidium italicum* Oudemans.

LIFE CYCLE AND SEASONAL HISTORY

The grasshopper mite in the adult as well as in the nymphal state passes the winter in the soil (Figs. 1 and 2). As soon as the weather warms up in the spring, the mites make their way to the surface of the ground. Here they run about, sun themselves, and seek grasshopper egg-masses. When a mite finds such a mass, it burrows down into it and engorges itself with the contents of several eggs (Fig. 1). In warm weather the engorged adult female mites begin egg laying in 5 to 17 days after their first feeding. The eggs are laid in chambers in the soil, the average number laid by a single female being approximately 4,700. Egg laying may be continued over several weeks, and during this time, many egg-masses may be laid. The engorged nymphs, on the other hand, must first pass through the preimaginal pupal stage before they can become adult.

The eggs hatch in 15 to 28 days at temperatures varying from 65° to 75° F. At higher or lower temperatures the incubation period may be correspondingly shortened or lengthened. The larvae which hatch from the eggs are active six-legged mites (Fig. 1). During favorable weather, these mites run over the surface of the soil and over plants or other materials and seek grasshoppers to which to attach themselves and from which to obtain their nourishment. A larva remains attached to the body or to the appendages of a grasshopper for 8 to 14 days if pos-



(The various stages are not drawn to actual size nor to scale.)

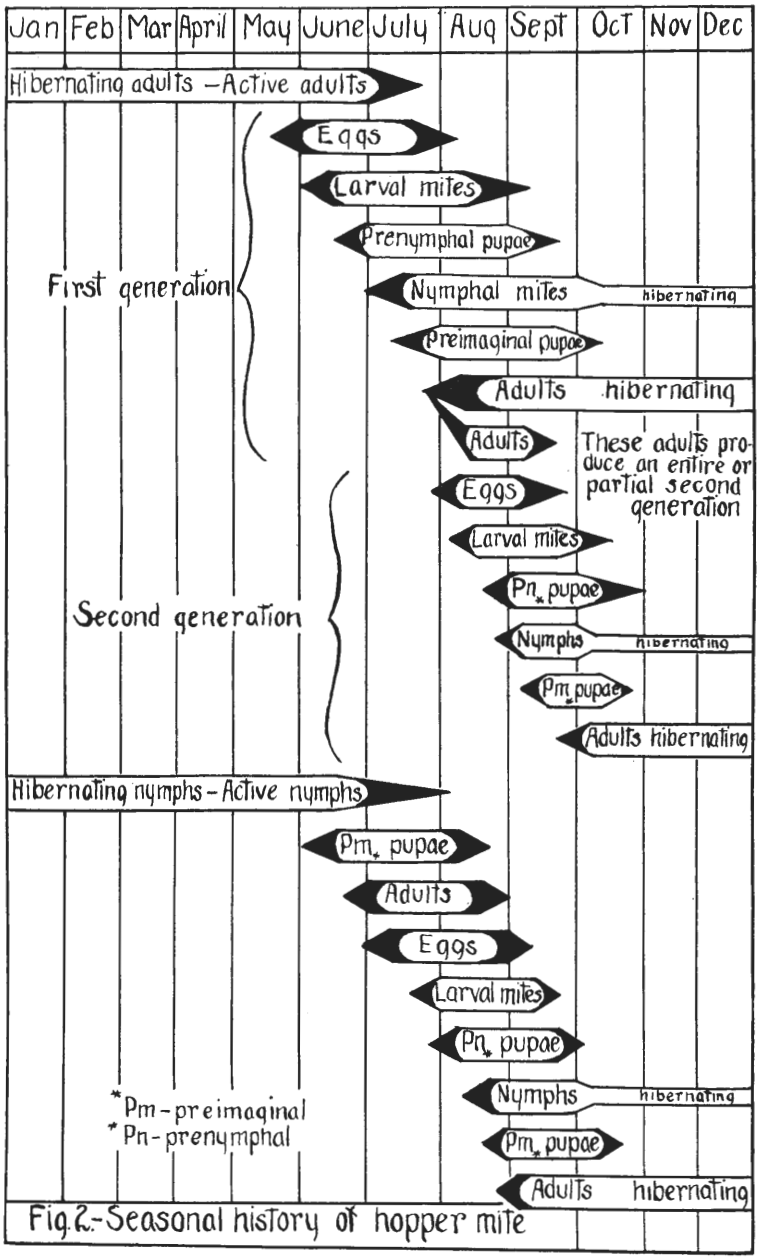


Fig. 2.- Seasonal history of hopper mite

sible and engorges itself with the blood of the host. At the end of the feeding period the larva drops from its host, burrows into the soil, usually constructs a chamber and inside of this chamber it pupates (Fig. 1). Pupation takes place usually within 3 days. The mite remains in the prenymphal stage for 7 to 18 days, the variation in time being largely accounted for by differences in temperature.

An eight-legged nymph emerges from the prenymphal pupa. The nymph, like the adult, prefers to feed upon the contents of grasshopper eggs (Fig. 1). The duration of the nymphal stage varies from 13 to 50 days, with 27 days as the average.

At the end of its period of life, the nymph constructs a chamber in the soil and inside of this transforms into a preimaginal pupa (Fig. 1). From 1 to 5 days or more are required for this transformation. The duration of the preimaginal pupal stage under favorable conditions varies from 9 to 18 days, but this period may be considerably prolonged under such adverse conditions as colder temperatures.

Most of the mites which become adult during the summer or early fall do not lay eggs during the same summer or fall, but they pass the remainder of the year, winter and early spring, in the adult state in the soil (Fig. 2). However, a small percentage of the mites that become adult in the summer do mate and lay eggs. In such cases the preoviposition period of these adult mites is sometimes only 5 days. The eggs laid by these mites hatch and such mites under favorable circumstances have sufficient time to pass through their various stages and become adult before winter sets in. Others develop as far as the nymphal stage and in this state hibernate successfully.

Under the usual South Dakota conditions, therefore, one complete and one partial generation of grasshopper mites are produced during a year. Under favorable circumstances the entire life cycle of a grasshopper mite may be completed in 61 days.

The life cycle of the grasshopper mite (Fig. 1) may be outlined in skeleton form as follows:

1. Adult mite unengorged
2. Adult mite engorged
3. Egg
4. Active larva recently hatched
5. Active larva engorged and parasitic on a grasshopper
6. Active larva engorged and no longer on grasshopper
7. Inactive swollen larval mite
8. Prenymphal pupa
9. Active nymph
10. Inactive engorged nymph
11. Preimaginal pupa
12. Adult mite

The seasonal history of the grasshopper mite in South Dakota is indicated in Fig. 2.

ADULT MITES

Description

Adult male unengorged: The entire body shaped like a plumber's plummet (Fig 3). The length and width of the body, excluding the appendages are quite variable, but the majority of specimens come within the following measurements: length 1.2 to 2.7 mm.; width 1 to 1.5 mm. Body and appendages scarlet. The entire body, except posterior dorsal plate, covered with an abundance of plumose scarlet hair. The posterior dorsal plate and the appendages also provided with plumose scarlet hair but not as abundantly as body. When viewed at certain angles, the hair on the body and appendages has a whitish instead of scarlet reflection.

Cephalothorax, approximately one-fourth the length of abdomen, wider than long, inserted in an anterior emargination of the abdomen; the base somewhat hidden by the overhanging abdomen, more so in partly and fully engorged specimens. A pair of eyes on a low rounded pedicel situated near each lateral edge of the cephalothorax, about midway between the anterior and posterior edges, the outer eye of each pair the larger. Dorsal groove of cephalothorax expanded at its middle into an enlarged area bearing two long unbranched hairs. Palps, flanking the oral tube laterally, directed anteriorly but with the distal ends pointing ventrally and posteriorly. Seg-

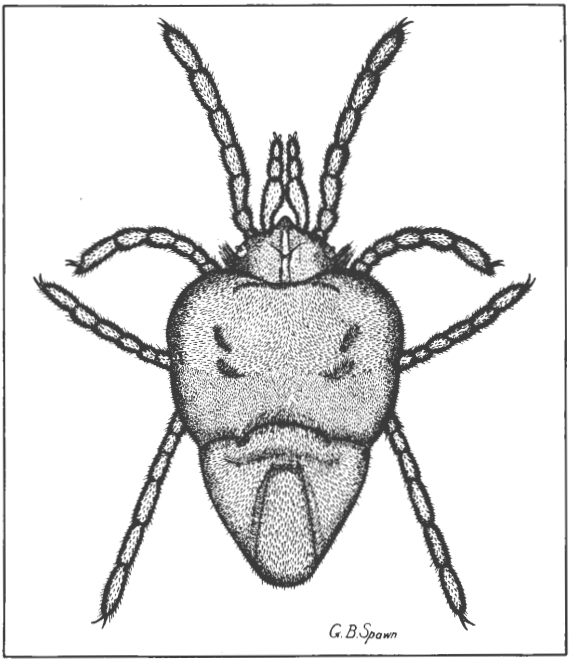


Fig. 3. Adult male unengorged

ments one and three of palps each slightly less than one-third as long as segment two; segment four, not including the claws, less than one-half the length of segment two, but longer than either segment one or three. Thumb (segment five) cylindrical in shape, of uniform diameter throughout, about one-fourth as wide as long. Segment four with two stout terminal claws, the inner the smaller. The outer surface of segment four bears near its lower edge usually three very heavy spines, nearly equal in size. These spines may be reduced to two or increased to four in some specimens. At times, the number of these spines differs on the right and left palps of the same mite. The inner surface of segment four bears a variable number of heavy spines, usually a total of seven in two irregular rows. However, in some specimens these spines are reduced to a total of four or increased to eight. Along the dorsal edge of the inner face of segment four is a row of long spines. These vary in number but usually total six to eight. Blade of mandibles scimiter-like, the inner edge serrate.

Abdomen widest near anterior end, decreasing in width posteriorly, the posterior edge rounded. Abdomen constricted near the middle, a transverse groove running through the constriction and dividing the abdomen into two halves, an anterior and a posterior. A second and more prominent groove, anterior to the median, divides the anterior half of the abdomen into two parts, a larger anterior and a smaller posterior portion. This groove does not always extend across the entire body. A large ovoid plate at the posterior end of the dorsum of the abdomen, about one-third to two-fifths as long as abdomen. This plate is sunk more or less beneath the level of the surrounding integument and, therefore, the plate seems to vary much in size and shape. A transverse groove may be present a short distance anterior to this plate, dividing the posterior half of the dorsum of the abdomen into two unequal parts, but this groove does not extend across the entire body. In many specimens there is a more or less prominent groove in the integument immediately anterior to the dorsal plate. This groove delineates the edges of the dorsal plate which is beneath the integument.

The coxae of the legs on the right side of the body widely separated from the coxae of the left side. The coxae of the second pair of legs on one side of the body widely separated from the coxae of the third pair of legs on the same side of the body. The coxae of the first and second pair of legs of one side of the body contiguous, as are also the coxae of the third and fourth pair of legs of the same side. A deep transverse prominent groove in the integument of the ventral part of the abdomen between the second and third pair of coxae. A second but less prominent transverse groove anterior to the prominent one but immediately posterior to the coxae of the second pair of legs. A median longitudinal groove extending from the anus to the posterior end of the abdomen. A short but conspicuous transverse groove immediately anterior to the anus.

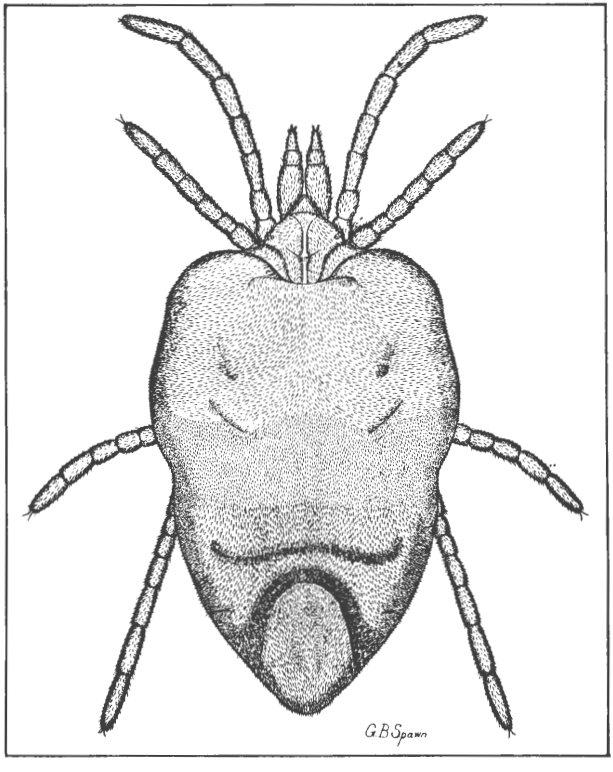


Fig. 4. Adult male engorged

Genital opening halfway between the hind coxae. Anus about halfway between the genital opening and the posterior margin of the body.

First pair of legs as long or nearly as long as body; fourth pair of legs next in length, followed by the second pair. Each tarsus provided with two curved, sharply pointed claws, those of the first pair of legs much reduced in size. Tarsi of second, third, and fourth pair of legs very similar in shape, obliquely truncate at distal end. Tarsi of first pair of legs larger than tarsi of other legs, less obliquely truncate at distal end.

Adult male engorged: Very similar to unengorged males except that the abdomen is now larger and much swollen (Fig. 4). The grooves largely eliminated and, in well engorged specimens, present only as faint indications. Size variable, depending to some extent upon amount of food taken. The largest specimens measured 3 mm. long and 1.5 mm. wide.

Adult female unengorged: Similar to male but larger. Anterior end of abdomen wider; posterior end of abdomen less acute than in male. Legs relatively shorter. Posterior dorsal plate larger. Genital opening larger than in male. Grooves more prominent. Length of body excluding appendages 2.2 to 3.5 mm.; width of body 1.3 to 2 mm.

Adult female engorged: Similar to unengorged females except that the abdomen has become larger and more swollen. The grooves are less prominent and may be difficult or impossible to see in resting well engorged specimens. The dorsum of the anterior end of the abdomen overhangs the cephalothorax in resting specimens, largely concealing the cephalothorax when the mites are examined from above. Length of body excluding appendages, variable, the largest specimens 5.0 mm. long and 2.7 mm. wide.

Oviposition and Feeding in Spring

Under normal conditions a female mite that is ready to lay eggs constructs a small smooth-walled chamber in the soil and in this chamber she deposits a mass of eggs (Fig. 1). These chambers are usually ½ inch to 4 inches below the

surface of the soil. Frequently such egg masses are close to grasshopper egg pods. A collection of eggs, if fairly large, forms a hemispherical heap on the floor of the chamber. These masses vary considerably in size, the largest measuring 10 mm. in diameter and 5 mm. in height. The eggs are very conspicious in a dark soil for they are yellowish-orange.

As a female mite lays her eggs, her body shrinks. If a large number of eggs are laid, the body may shrink until it shows some transverse grooves but after feeding becomes plump again and the grooves disappear.

An adult male and a female mite were placed in a 1-ounce seamless tin box containing a damp block of plaster of paris and three grasshopper eggs of *Melanoplus differentialis* Thos. Ten such boxes were prepared. They were examined daily. When it was necessary, moisture was added to the block of plaster of paris and fresh grasshopper eggs were substituted for the eggs that were collapsed because the mites had fed upon them. The mites used in this experiment were collected in the field on the first warm day of spring (April 26, 1940) and at this time neither the males nor females had engorged themselves with food.

Twenty-four hours after the mites had been confined in the boxes, every mite had fed and become much swollen, the females much more than the males. The female mites laid their first batch of eggs 5 to 17 days after their first feeding, the period average being 10.8 days. The number of grasshopper eggs that each pair of mites consumed during the entire preoviposition period varied from 3 to 7, the average being 5 eggs. The grasshopper eggs that were used by the mites in feeding were collapsed and very little fluid remained within the shells.

After it had been determined that an average pair of mites consumed the contents of 3 to 7 grasshopper eggs during the preoviposition period of the female mite in the spring, the experiment was continued in order to learn the total number of grasshopper eggs that could be destroyed by a pair of mites in the spring. In this experiment no grasshopper egg was removed from any box containing a pair of mites until the contents of the egg had been entirely or almost entirely removed and the shell had collapsed. The largest number of grasshopper eggs destroyed by any pair of mites after the female had started oviposition was 16, and the smallest number was 2.

EGGS OF GRASSHOPPER MITE

Description of Eggs

Eggs recently laid are spherical, yellowish-orange, and about 0.125 to 0.145 mm. in diameter (Fig. 5). An individual egg is visible to the naked eye with fairly good sight. The shell of the egg is smooth and shining and shows no markings

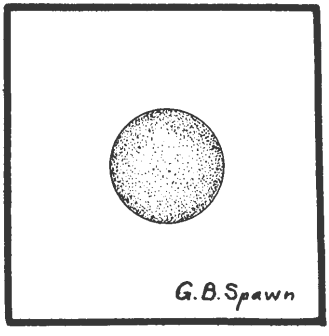


Fig. 5. Egg of grasshopper mite

even when looked at through a microscope with 350 magnification power. The shell is thin and so transparent that one can readily see the contents of the egg.

Average Number Laid

Ten pairs of mites were kept in 10 tin boxes as discussed on page 13 (under "Technique Used in Determining the Average Number of Eggs Laid by a Grasshopper Mite"). The average number of eggs laid by these mites was 4,768. The largest number laid by any one mite was 9,542, while the smallest number was 1,027 (see table).

NUMBER OF EGGS LAID BY TEN DIFFERENT MITES AND DATES OF LAYING
(EXPERIMENT BEGUN APRIL 16, 1942)

Date of laying	Number of eggs laid by mite number—									
	1	2	3	4	5	6	7	8	9	10
April 20						1,058				
April 21										
April 22										
April 23								1,941		
April 24										
April 25		1,577		946	307					
April 26			1,604		677	1,495				
April 27									3,707	
April 28			40				82			
April 29		30					2,954			
April 30			1			15			2	
May 1	1,237						28			
May 2	2,264		840		12	died		1		4
May 3			116		677					1,023
May 4			40		3,662			2,374		
May 5		7	10				548	4	2	
May 6					186		406		2,719	
May 7			872	614				855		
May 8	2,110		1,113		178		533	322	730	died
May 9	5		2	14	973			501		
May 10		died		died	105		4		2	
May 11							3			
May 12					4			1,240	1	
May 13			died						875	
May 14							5	207	193	
May 15							4	5		
May 16					873					
May 17	3							263		
May 18					18		1	22		
May 19	died				65			22	50	
May 20								36	14	
May 21					7					
May 22					6		193			
May 23					10		459		2	
May 24					18		7		3	
May 25					20		2	60	860	
May 26					20				10	
May 27					144			1	12	
May 28					9				60	
May 29								7	300	
May 30					39					
May 31					died					
Totals	5,619	1,614	4,638	1,574	8,010	2,568	died June 2 5,229	died June 2 7,861	died June 16 9,542	1,027

Egg laying by any one mite was not confined to a single mass nor to a single day. One mite in this experiment laid eggs on only 2 days, while at the other extreme, another laid eggs on 22 days. The largest number laid by any one mite in 24 hours was 3,707; the smallest number was 1. Not a single mite finished egg laying in one day. There seemed to be a correlation between the number of eggs laid and longevity of the female mites, for those mites that had the longest life span laid the largest number of eggs. Although the majority of the female mites died within 1 to 4 days after laying their last eggs, some of them survived 7 to 18 days. Even after the female mites had died, their bodies still were somewhat swollen with eggs.

Technique for determining average number. To determine the average number of eggs that a female mite may deposit, mites were collected early in the spring when they made their first appearance on the surface of the soil. Such mites, both male and female, were not engorged with food. A male and female mite were placed in a 1-ounce tin seamless box to which had been added a damp block of plaster of paris and three grasshopper eggs. Ten such boxes were stocked with mites. The boxes were kept in the laboratory and examined once a day between 8 and 11 a.m. Whenever necessary, water was added to the block of plaster of paris or a new supply of grasshopper eggs was added and the old supply removed.

The mite eggs were removed, counted, and recorded as soon as they were found. They were deposited by the mites either on the block of plaster of paris or on the sides or bottom of the tin container. Each box was marked with a blue-china marking pencil, the same data being placed upon the cover and bottom.

Through experiments conducted in a previous year, it was deemed inadvisable to use damp soil in the tin container in the experiment discussed. When damp soil was used, it was sometimes impossible to locate all of the eggs laid, or if all of them were located, the time consumed in finding them was so large as to make it compulsory to change this technique.

Counting the eggs laid. The eggs of the grasshopper mite are usually laid in masses, though occasionally a few isolated eggs may be deposited. The eggs in a mass normally are held together by a sticky material, but this material is readily soluble in water. To count the eggs the following equipment was used: a binocular microscope having magnification powers of 7, 14, and 20 diameters; a desk lamp to furnish good illumination; several blocks of plaster of paris; a camel's hair brush; water and a hand tally.

The camel's hair brush was dipped in water and applied to the egg mass to soften it. The mass was then broken up by means of the brush. Individual eggs or small masses of them were lifted away and deposited upon a block of plaster of paris. Water was added to the small masses of eggs resting on the block of plaster of paris and then the masses were gently stroked with the brush until the eggs separated. As the eggs were separated they were counted with the aid of a binocular microscope. When a large number of eggs were placed on a block of plaster of paris at one time it was usually necessary, in order to avoid confusion, to pick the eggs up with the brush one or a few at a time as they were counted. As the eggs were counted, the number was recorded by means of a hand tally.

Incubation of Eggs

Development of embryo and hatching. When recently laid eggs are incubated for 4 to 7 days at temperatures varying from 65° F. to 75° F., about one fourth of the contents of each egg, located on one side, becomes lighter and lighter in color, while the remainder of the contents retains the yellowish-orange color. The

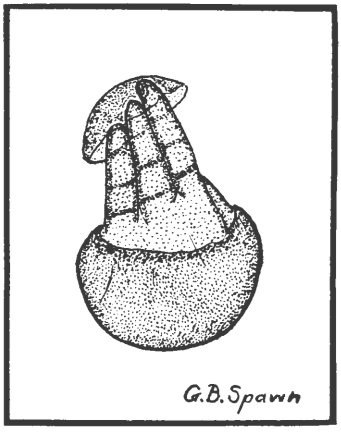


Fig. 6. Larval mite hatching

lighter mass in the eggs is the area where the appendages (legs and palps) of the developing larva will be located, and the yellowish-orange mass will contain the body.

After the eggs have been incubated 6 to 14 days or more at the temperatures indicated above, the legs and palps are straightened and extended stiffly from the body in the form of a conical mass (Fig. 6). The shell is ruptured through this procedure along a more or less irregular circular line a short distance above the equator. Through this opening the appendages of the developing larva are extended but the body remains lying back downward within the remainder of the shell. However, the entire larva including the appendages is still enveloped in a membrane which must be shed before the larva is free to run about.

After a larva ruptures its eggshell, it requires another 6 to 14 days or more to develop before it is ready to shed the membrane that still envelops it. The entire incubation period, extending from the time the egg was laid until the larva breaks its shell and sheds the membrane, averages 15 to 28 days at temperatures varying from 65° to 75° F.

Technique used in incubating eggs. Eggs that were to be incubated were transferred to 1-ounce or 2-ounce seamless tin boxes as soon as they were laid. These boxes were provided either with firmly compacted damp sandy loam soil or with a thick, damp layer of plaster of paris. The eggs were placed upon the surface of the soil or plaster of paris with a fine camel's hair brush.

The contents of the boxes were examined daily between 8 and 10 a.m., and the progress in incubation of the eggs was studied with a microscope. When water was needed, it was added to the soil or plaster of paris with an eye dropper. Care was taken to keep the surface of the soil or plaster of paris damp at all times. The cover as well as the bottom of each box was labelled with the proper data, a blue-china marking pencil being used for this purpose.

Unfertilized eggs do not develop. Unfertilized eggs of the grasshopper mite do not develop embryos, but ultimately dry up. The color changes described as occurring in fertile eggs during the first 4 to 7 days of incubation do not occur in fertilized eggs. These eggs remain clear and yellowish-orange until they dry up. Unfertilized eggs are laid more frequently as the mites approach the end of their natural life than as they begin their oviposition period.

LARVAL STAGE OF GRASSHOPPER MITE

Description of Recently Hatched Larva

Color, yellowish-orange and scarlet; the anterior two-fifths of body yellowish-orange, the posterior third orange tinged with scarlet, and a scarlet band, more or less irregular in shape, extending transversely across the body joining the eyes on one side of the body with those of the other side (Fig. 7). Legs transparent yellowish, usually darker at joints. Size of body 0.175 to

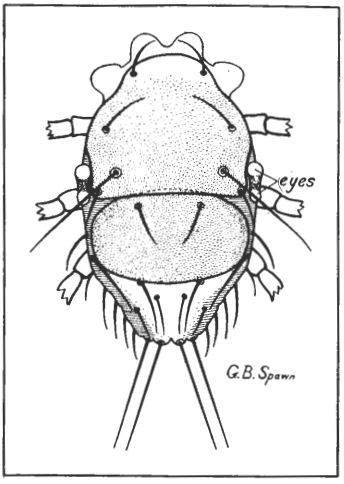


Fig. 7. Larva, dorsal view

0.2 mm. long and 0.11 to 0.13 mm. wide. Shape of body roughly pear-like, the posterior third the narrower. From a dorsal view the anterior edge of the body smoothly rounded, the posterior edge somewhat crenulated.

A large more or less hexagonal-shaped shield covering slightly more than the anterior third of the dorsum of body. This shield completely covers the mouth parts and palps from above. Four pairs of setae on this shield; one unusually long seta near each posterior lateral angle. Four hyaline lobes extending anteriorly from beneath the forward border of the shield. Laterad of the posterior lateral angles of the shield are a pair of bright scarlet-colored prominent eyes. Posterior to the hexagonal shield on the dorsum of the cephalothorax is a wide somewhat quadrilateral shield bearing a single pair of setae anteriorly. The anterior and posterior shields finely granulated.

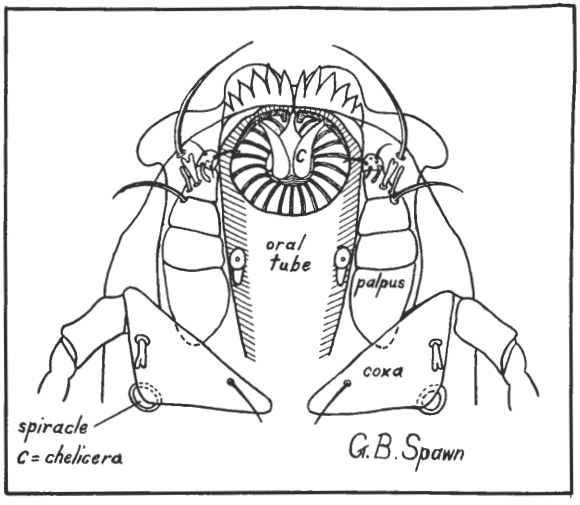


Fig. 8. Mouth parts of larva

Two pairs of long setae, two-fifths as long as body, attached to the posterior margin of the body. Remainder of body provided dorsally and ventrally with many pairs of setae.

Blades of chelicerae scimiter-like, and when retracted, located in a tubular oral sheath (Fig. 8). The tubular oral sheath is attached to the anterior ventral part of the cephalothorax and is not visible from above. Mouth of oral tube large, the outer rim of the tube open in front and with numerous ridges. A pair of small, short, heavy sense organs that are unsegmented and bluntly conical, attached to ventral surface of oral tube. Anterior to the mouth of the oral tube and beneath the four hyaline lobes are two small hyaline plates, each ending in six minute

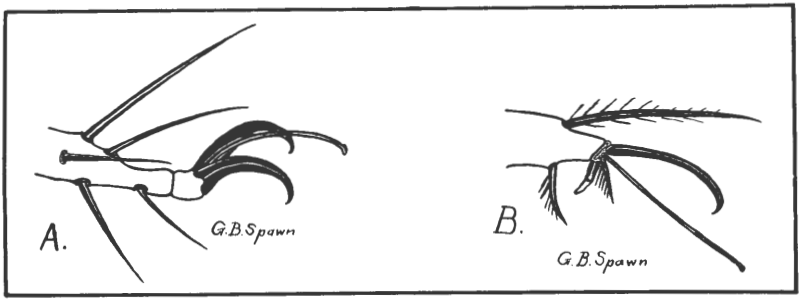


Fig. 9. (A) Pretarsus of first leg of larva (B) Pretarsus of second leg

finely pointed teeth directed forward. Palpi short, segment IV with two spines, the inner the larger, and bifid. Thumb (fifth segment) of each palpus terminal, short and bearing several hair and sense organs.

Three pairs of stout legs. The coxae large, those on right half of body and those on left half of body contiguous. A short bifid sense organ near the distal end of each coxa. Pretarsi small and slender, each provided with a long, tactile, curved, hair-like dactylopodite. Pretarsi I and II each provided distally with two slender claws (Fig. 9, A). Pretarsi III each provided with one long slender claw, a two-segmented seta and three plumose spines (Fig. 9, B). A large spiracle situated beneath the outer, lower angle of each fore coxa.

The integument of the abdomen finely pleated more or less transversely.

Behavior of Larval Mites Shortly After Hatching

Larval mites exhibit a strong gregarious instinct shortly after hatching. Occasionally clusters composed of several thousand individuals may be found but more frequently clusters are composed of less than 100 larval mites. The individuals forming a cluster may be several layers deep and usually are so arranged as to have the anterior end pointed toward the center of the cluster. The clusters are usually formed in cavities in the soil, under trash lying on the surface of the ground, and under masses of dried cow dung.

Under laboratory conditions the larvae that hatched in tin seamless boxes containing a damp piece of plaster of paris, clustered as they did under field conditions. When such boxes were opened in daylight or under an ordinary electric lamp, the larvae immediately became active and ran about, but when the lids were placed upon the boxes, the larvae soon clustered together again to form one or more masses of mites.

When adult or immature grasshoppers were added to a tin box containing larval mites and a damp block of plaster of paris, many of the mites were found fastened to the bodies or appendages of the grasshoppers within an hour.

Larva's Attack on Grasshoppers

Species of grasshoppers used as hosts. There are 115 species or varieties of grasshoppers that have a portion of their range within South Dakota, and every one of these may be used as a host by the larval grasshopper mite. Even the lubber grasshopper, *Brachystola maga* (Girard) may act as a host.

Species of grasshoppers whose tegmina and wings are abbreviated when the grasshoppers are adult are not immune from the attack of larval mites. However, they will not harbor nearly as many mites on the average as do the fully winged species.

Number of larval mites on grasshoppers. The number of larval mites that may be found on grasshoppers at any one time varies considerably. In general, more of the mites are on adult grasshoppers than on nymphs and more are found on older nymphs than on younger. Ordinarily 0 to 35 larval mites are found on a grasshopper at one time, but this number may be greatly exceeded. For instance, on an adult female *Dissosteira carolina* (Linn) 175 mites were found attached to the body and appendages.

A grasshopper may become infested with larval mites from the first instar of its existance through its adult life. During all this time mites may attach themselves to the grasshopper, engorge, and then drop off. Since the same grasshopper is subject to infestation daily, larval mites of all ages and sizes may be found on it at one time. The same grasshopper may never be free from mites during its life except for short periods after hatching and after molting. Finding a grasshopper that is free from mites does not mean that it has not had an infestation of mites nor that it will remain free from them. When a grasshopper has a heavy infestation of mites, the mites usually vary in age and size from those just recently hatched to those fully engorged and ready to drop from their host.

Where they attach themselves. The larval mites attach themselves to the bodies of grasshoppers or to their appendages wherever the sclerotization is absent or very thinly developed. Another factor which is important in determining the location of the attachment of the larval mites is the desire of the mites to wedge their bodies underneath or between structures of the body.

When the larval mites hatch from the egg, they are the size of the point of an ordinary pin. They are visible to the naked eye of a person with good sight as minute reddish specks. After the larvae have fed they grow larger, and when they are fully engorged, they are about one-fourth to one-third of the length and breadth of an average grain of wheat.

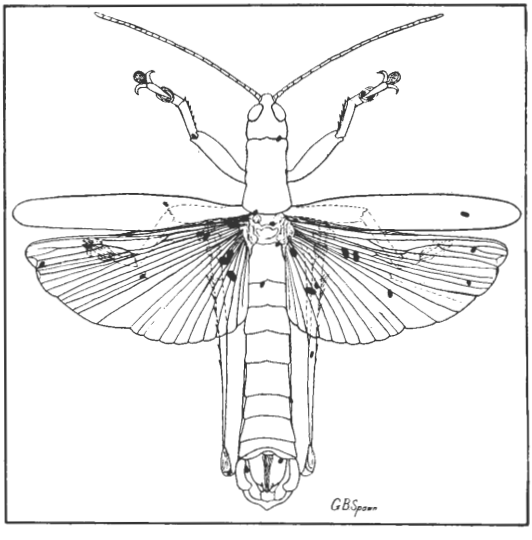


Fig. 10. Grasshopper with larval mites attached to body, wings, and legs

Fig. 11. Adult two-striped grasshopper Melanoplus bivittatus (Say) with larval mites attached to body and wings

The larval mites may attach themselves to grasshoppers and feed upon them in all their instars, from the first to the adult. On the adult grasshoppers, the favorite location is in the folds or plications of the hind wings (Fig. 10). Here the mouth parts of the mites are inserted into the wings adjacent to a vein, either longitudinal or cross. Either the upper or under surface of the wing may be chosen but usually it is the upper. The location next favored is the dorsum of the mesothorax and metathorax where the sclerotization is meager (Figs. 11, 12). Next, the point of union of the bases of the wings and tegmina with the body are chosen. The mites may also attach themselves to the under surfaces of the tegmina

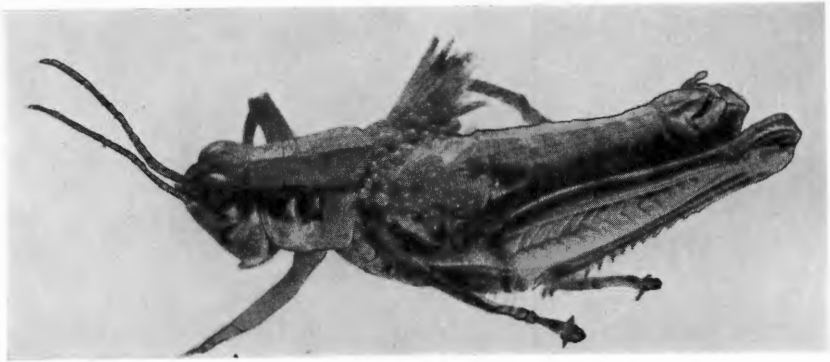


Fig. 12. Grasshopper, Melanoplus foedus fluviatilis Bruner, with wings removed to show large number of larval mites attached to body

Fig. 13. Immature two-striped grasshoppers, Melanoplus bivittatus (Say) showing larval mites attached to body between wing pads

but this does not occur frequently. Mites are occasionally found fastened to the intersegmental membranes of the abdomen and to the dorsum of the first and second abdominal segments.

On the head, mites may be found attached to the antennae and to the membranes which fasten the mouth parts to the head. Occasionally a mite or two is found attached to the neck membranes of grasshoppers. On the legs the mites are usually attached to any of the non-sclerotized membranes found in the joints, including those of the tarsus. Quite often mites are found attached to the tympanic membranes of the ears but ordinarly only one is found attached to such a membrane at one time. Occasionally a mite fastens itself underneath the cerci or supra-anal plate, to the pallium, or between the valves of the ovipositor.

In nymphal grasshoppers with wing pads well developed, the mites prefer to attach themselves to the body between the pads or to the pads themselves (Fig. 13). On the remainder of the body and its appendages the mites usually attach themselves in locations as described for the adult grasshopper. However, occasionally mites are found attached to the tibiae or femora of nymphal mites instead of to the intersegmental membranes of the legs. When this occurred, the nymphs were usually in the first or second instars.

How larvae attach themselves and feed. The larval mites have a cylindrical oral tube inside of which are a pair of chelicerae (Fig. 8). When the chelicerae are not in use, they are retracted within the tube. When they are functioning, they extend at least partially beyond the mouth of the tube. The mouth of the tube is directed ventrally and anteriorly and has a broad rolled-over rim which is narrowly incomplete anteriorly. Numerous ridges run radially over the rim.

The chelicerae are roughly scimiter-like in shape. When they are retracted within the tube, they lie somewhat parallel to each other and their distal ends are directed mainly anteriorly, but when they are extended out of the tube, their distal ends diverge widely.

A larval mite is able to work its chelicerae through an unsclerotized or weakly sclerotized part of the integument of its host. Probably a suction process of the mouth of the oral tube aids the legs and palps at this time in holding the larva to its host. However, the insertion of the chelicerae must be difficult for them when they are on a flat exposed surface, for the mites prefer to crawl between or underneath structures of the body, thus taking advantage of the pressure against their bodies to help them drive the chelicerae into the host. After the sharp ends of the chelicerae have penetrated the integument, they are driven deeper into the host and the tips of the jaws are diverged more and more until they are directed laterally. Through this means the mites are anchored firmly to the host.

When a mite desires to remove itself from its host, it so moves its chelicerae that their tips are directed forward and more or less parallel, and then the jaws readily slip out of the integument of the grasshopper.

The food of the larval mites evidently must be mainly liquid and probably consists chiefly of blood. When the scimiter-like jaws are inserted through the integument of the host, a gash is cut. The mouth of the oral tube, in the meantime, is fastened to the integument and through this tube the blood of the host passes into the mite. A careful examination of the chelicerae under an oil immersion discloses what appears to be a tube running from the tip of the chelicerae into the base. If this is a tube with an opening at the tip of the chelicerae, it may have the function of conducting an anti-coagulant, which would make it possible for the mite to feed for many days without removing the chelicerae from the host.

Length of feeding period. The length of time that a larval mite spends feeding upon a grasshopper varies with many circumstances. If the larval mite is permitted to engorge to capacity and is not disturbed, knocked off, or forced to leave its host because the host molted, the mite may engorge itself for 8 to 14 days. Under such circumstances, the larval mite reaches its largest size.

However, the period of engorgment may be shortened for one reason or another and then the engorged larva is correspondingly smaller. Under control conditions larvae have been forced to leave their grasshopper host after 3 days of feeding, and these larvae did not die but burrowed into the soil and passed into the prenymphal pupal stage. Such larvae were less than a third grown and formed very small prenymphal pupae. Such pupae gave rise to nymphs which acted normally and fed upon grasshopper eggs when given the opportunity.

Effect of larvae on grasshoppers. Larval mites have little direct effect upon the health of grasshoppers except possibly to weaken them a trifle. They certainly do not prevent nymphal grasshoppers from maturing and becoming what look like normal adults. Some nymphal grasshoppers that are very heavily infested with larval mites do not seem to be as vigorous and active as uninfested grasshoppers. Even though some larval mites may be attached to the wing pads, the pads do not seem to be seriously damaged, for when the nymph molts to become an adult grasshopper, the wings of the adult seem to be normal in every way. This is true even though the mites may be abundant and large enough on the pads or at their bases to cause the pads to diverge at abnormal angles.

When adult grasshoppers are infested with large numbers of larval mites, the great majority are attached to the upper and under surfaces of the hind wings, and on the dorsum of the mesothorax and metathorax. When such mites are large, they may prevent the grasshopper from properly folding the wings. As a consequence the tegmina, at times, cannot be folded so that they lie over the abdomen when they are not in use, nor can the second pair of wings be always folded neatly under the tegmina. As a consequence normal flight may be interfered with

or flight may even be impossible. Furthermore, as such insects crawl and hop about in their normal habitats, the tegmina and second pair of wings are much battered and broken, at times so badly as to be reduced to mere stubs. These stubs have led to the rather common but erroneous belief that the larval mites actually eat off the wings of grasshoppers.

Badly infested adult grasshoppers may not live as long as uninfested grasshoppers on an average, but if this is true it might be due largely to the fact that they become easier to catch by their biological enemies or easier to contact by their parasitic enemies. Adult grasshoppers are not much weakened through an average infestation of mites and will mate, and the females will lay their usual quota of eggs. Extremely heavy infestations continued throughout the life of female grasshoppers might weaken them enough to interfere with oviposition or reduce the number of eggs laid, but such conditions would be rather unusual.

Period that larvae can live without food. A series of experiments were conducted in the laboratory to determine the length of time that larval mites could remain alive without feeding. Mites that had recently hatched were placed in tin salve boxes containing damp blocks of plaster of paris. The boxes were kept in a laboratory having a temperature that varied from 65° to 85° F. The boxes were examined daily, and whenever it was necessary, water was added to the blocks of plaster of paris to keep them damp. Under these conditions, the maximum length of time that the larval mites remained alive was 28 days.

In a warm dry atmosphere the larval mites usually survived for only 1 to 5 days, the longevity depending mainly upon the temperature, relative humidity, and circulation of air.

In a refrigerator in which a temperature of 38° F. was maintained fairly constantly, larval mites were kept alive for 2 months inside tin salve boxes containing damp blocks of plaster of paris. At the end of this time the experiment was discontinued, for it was evident that the mites would remain alive considerably longer and that they would not encounter such a prolonged cold spell in their natural environment.

From the experiments conducted, it may be concluded that the larval mites under favorable conditions can remain alive for a month or more without feeding or becoming attached to a grasshopper host. Dry soil and dry hot winds cut short the length of life of the larval mites that have not attached themselves to a grasshopper host. Cool weather and a soil containing a fair amount of moisture tends to prolong their life.

Seasonal Abundance of Mites in Larval Stage

Larval mites may be found attached to grasshoppers in South Dakota, usually from early in June to the latter part of October, though this period is greatly influenced by prevailing weather in the early spring and late fall. However, the bulk of the larval mites are found upon grasshoppers from the middle of June, through July, August, and the first half of September (Fig. 2).

Detachment of Larvae from Grasshoppers

How and why detachment is made. A mite usually remains attached to an adult grasshopper's body or an appendage until it has fully engorged itself; then it withdraws the chelicerae from the host and drops off. However, sometimes the mites attach themselves to a grasshopper that is in a nymphal stage, and this nymph may molt before the mites have become fully engorged. Under such circumstances, the mites may remain on the exuvium and die still fastened to it, but if they are a third or more grown, they usually withdraw their chelicerae from

the exuvium, drop from it, and burrow into the ground to transform into prenymphal pupae. The same process occurs with mites which are attached to grasshoppers that are killed.

Infested grasshoppers that were crowded into glass jars soon lost many of their large mites. This probably was due to a combination of causes such as high temperature, increase in humidity, and unusual activity of grasshoppers. At times some of the mites may be scraped, jarred, or kicked off the body or appendages of their host, but this does not take place frequently under normal conditions, for the mites are fastened very securely to the integument of the grasshoppers. The mating activity of grasshoppers may remove a few mites but not many.

Transfer to another grasshopper. Five adult two-striped grasshoppers, *Melanoplus bivittatus* (Say), that were heavily infested with mites were decapitated and placed in glass containers holding sterilized soil. The attached mites had all begun to engorge but they varied in age from less than a day to mites that were fully engorged and about ready to drop from their host. Five uninjured mite-free grasshoppers of the same species, two adults and three nymphs in the fifth instar, were added to the container. The grasshoppers added were first carefully examined with a binocular microscope to be certain that they were free from mites. No green food was added to the container, but the uninjured grasshoppers were given water to drink.

A second experiment was set up which was an exact duplicate of the first. A third and fourth experiment was also set up but in this case, specimens of the differential grasshopper, *Melanoplus differentialis* (Thos), were used throughout.

Twelve hours after the experiments were begun, most of the larger mites had detached themselves from the decapitated grasshoppers. Some of the mites had burrowed into the soil, others were still moving about on the surface of the soil. None of the specimens had become attached to the normal uninfested grasshoppers. A few of the mites had not dropped from the decapitated grasshoppers but most of these mites were small.

The normal grasshoppers were carefully examined for mites at the end of 24, 36, 48, 60, 72, 84, and 96 hours, but none of the mites had made their way from the decapitated to the normal grasshoppers. At the end of the experiment, some mites, mostly small, were still attached to the decapitated grasshoppers but were dead.

In a second set of experiments, grasshoppers that had several newly hatched mites crawling over their bodies but no attached larvae were decapitated and placed in glass jars containing sterilized soil. The same two species of grasshoppers were used in this experiment as in the preceding, and the other conditions and details already discussed for the preceding experiment were duplicated in this experiment.

At the end of 12 hours, it was found that some of the mites had attached themselves to the decapitated grasshoppers, while others had found their way to the bodies of the uninjured hoppers and attached themselves.

In a third set of experiments, attempts were made to transfer larval mites in various stages of engorgement to mite-free grasshoppers. In these experiments a piece of the hind wing of an adult *M. bivittatus* or *M. differentialis* containing an attached mite was cut out with a pair of scissors and then gently pushed under the wing pads of a nymph of the same species of grasshopper. The mites were in different stages of engorgement and sizes and varied from minute mites recently attached and only slightly engorged to mites fully one-half engorged and 1 millimeter long. Twenty-four attempts were made to transfer larval mites in this way.

However, none of the mites attached themselves to the grasshopper to which they were transferred. In most of the trials, the mite died under the wing pad where it was placed and, strange to say, remained fastened to the piece of wing to which it was originally attached. In some instances the mite and the piece of wing to which it was attached slipped out from underneath the wing pads of the grasshoppers and dropped to the soil of the glass container. Here the mites either died or detached themselves and burrowed into the soil.

From the evidence obtained through these experiments, it is apparent that larval mites that have attached themselves to a grasshopper and have begun to engorge themselves will not migrate to another grasshopper and attach themselves and finish engorgement, even when their first host dies. They may, however, detach themselves, burrow into the soil, and pupate.

Description of Engorged Active Larva Recently Dropped from a Grasshopper

Color, scarlet. Size 1.8 to 2.2 mm. long and 0.9 to 1.2 mm. wide. Dorsum convex, venter flattened. Anterior edge of body more or less truncate, the posterior edge rounded (Figs. 14, 15).

A mite that has engorged itself for 10 days or more upon a grasshopper, is not only much larger than when first it hatched from the egg but is wonderfully different in appearance, especially when examined microscopically.

In the engorged larva, the entire body has become enormously swollen. The two dorsal chitinous plates which formerly were contiguous or nearly so are now widely separated, and since they have not increased in size, they cover only a very small portion of the body.

The body is constricted transversely in its mid area both on the dorsum and venter. Another but less prominent transverse constriction is present anterior to the principal constriction referred to, while still another is present posterior to it.

Two linear series of depressions extend lengthwise over the dorsum, but these depressions are deeper in some areas than in others and may even be absent in some areas. The deeper portions of the depressions, when present, are located in the following regions:

a. A pair of anterior, deep depressions anterior to the principal transverse constriction.

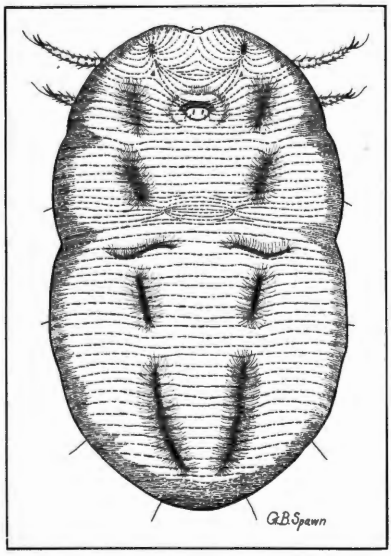


Fig. 14. Active engorged larva, dorsal view

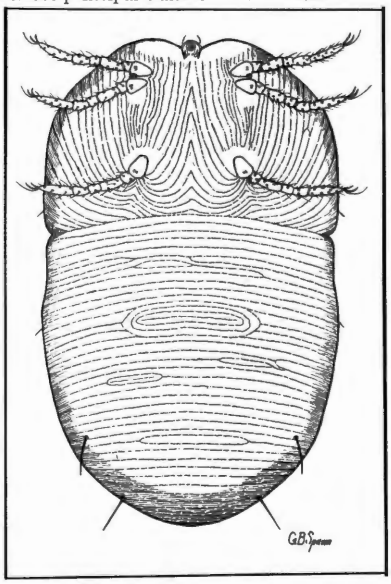


Fig. 15. Active engorged larva, ventral view

b. A second pair of anterior but short depressions located anterior to the principal transverse constriction but posterior to the preceeding.

c. A third pair of short depressions immediately posterior to the second pair and posterior to the principal transverse constriction.

d. A fourth and posterior pair of long depressions located on the posterior third of the dorsum. These depressions are deeper than the other depressions mentioned and converge posteriorly.

The venter has a deep unpaired median depression on the posterior third of the abdomen. Two additional pairs of depressions are located anterior to the unpaired median one, one pair immediately anterior to the principal median constriction of the body and one pair immediately posterior to it.

The legs are incongruously small. The coxae of the first and second pair of legs on the same half of the body are close together, but the coxae of the third pair of legs are now far removed from the second.

The integument of the larva is marked with numerous fine ridges which run for the most part transversely over most of the dorsum of the body and over the venter of the abdomen. Over the remainder of the body the ridges appear in concentric rings or in arcs or lengthwise. These fine lines mark the top edges of the pleats mentioned in the description of the larva just hatched.

Activity after detachment. After a mite has engorged and removed itself from a grasshopper, its main purpose is to burrow into the soil. In crawling about on the surface of the ground, the mite makes very slow progress, ½ inch to 1¾ inch being its maximum speed per minute. The mite at times uses only its legs in pulling its body along and frequently the palps are used in addition, but the enlarged swollen body, especially the abdomen, makes speedy locomotion extremely difficult. The abdomen is often used in aiding the legs and palps in locomotion. To do this, the mite arches its abdomen, presses the posterior end against the substratum and then the anterior end is extended forward. These movements may be repeated time and again. Or at times the legs and palps may pull the anterior end forward and then the posterior end may be raised, contracted, and brought forward.

The mites burrow into the soil to a depth of ½ inch to 4 inches or even more. Burrowing is accomplished through two principal sets of activities. One, and the least important by itself, is through the legs and palps pulling the body forward. The other is through a perculiar combination of movements in which the anterior part of the body or cephalothorax is used as a wedge and is forced forward. This movement is followed by a wave of contraction of the abdomen beginning at the posterior end and passing forward. In the meantime the legs and palps also tug away in an attempt to force the body through the soil. These movements are repeated again and again until the mite has reached its desired position in the soil.

Mites that are in the engorged state and that have removed themselves from a grasshopper are able to right themselves if they happen to turn over on their back. The legs are not used to accomplish this, for they are too short to reach the ground. However, the righting is done by contorting the body, and since the body is rounded dorsally and somewhat flattened ventrally, it is not a difficult task to roll over.

Mites that have made their way into the soil usually construct a chamber inside of which to pupate and later molt into a nymph. Sometimes no chamber is constructed and still pupation and molting takes place normally.

Engorged Inactive Larva

A larval mite that has removed itself from a grasshopper after engorging itself remains active from several hours to 2 days or longer. During the early portion of this time it burrows into the soil and then the mite rounds out its integument, eliminating all depressions and grooves except the principal constriction running

across the middle of the body. When the larval mite is in its ultimate typical swollen state, it can no longer move about and make use of its legs; as a matter of fact, the legs are usually extended out from the body rather stiffly. Even though it is touched, the mite moves neither its body nor legs. In size the mite measures approximately the same as it did when it first removed itself from the body of the host.

After the active engorged larval mite has become detached from its grasshopper host, it burrows into the soil and transforms into an inactive swollen larval mite. From a few hours to 48 hours are required for this transformation. Often an additional day is required before this inactive larval mite pupates. The period extending from the time the active larval mite drops from the host to the time of pupation (the prepupal period preceding the nymphal stage) is 1 to 3 days.

Larvae Do Not Attack Human Beings

Larval mites a few days old were used in several experiments to determine whether they would attach themselves to the skin of man as does the true chigger. In these experiments four men who were 21, 38, 55, and 58 years old acted as subjects. In each experiment two adhesive tape cells were placed over the skin and the larval mites were put in them. One cell was located on the right side of the abdomen about on a level where the men wore their trouser belts. The other was placed on the skin of the arm near the brachial artery in the break of the elbow.

The cells were made as follows: narrow strips of adhesive tape were fastened to the skin in such a way as to bound an area 1-inch square; a piece of muslin was then fastened over the square inch of skin with additional strips of adhesive tape. In each experiment 5 or 6 larval mites were put into a cell.

Each experiment was begun between 9 and 10 a.m. and on the following day at the same time the skin was examined to see if any mites had attached themselves. No larvae were found fastened to the skin in any experiment. Howard (6) reports that he twice placed large numbers of larval mites inside of his clothing, but that none of the mites became fastened to his skin. In South Dakota the grasshopper mite occurs commonly over the entire State and yet most of the State is free from chiggers that attack human beings. There would evidently not be freedom from chiggers if the grasshopper mite in its larval stage could attack human beings.

PRENYMPHAL PUPA

Description

A mite that has passed into the inactive engorged larval stage next develops into a prenymphal pupa. This development takes place within the skin of the larval mite. As development progresses, the body of the pupa together with its appendages becomes more and more clearly distinguishable through the larval skin. At first the skin and the developing pupa are not clearly separable, but as development continues the skin becomes more and more thoroughly separated from the developing pupa within. From a ventral view, it is readily seen that although the pupa is encased in the larval skin, the appendages are free but closely folded against the body. The four pairs of segmented legs are clearly visible through the larval skin and are folded in such a manner as to cover much of the ventral surface of the anterior half or two-thirds of the body (Fig. 16). The cephalothorax is separable from the abdomen and the palps are also visible. The color of the prenymphal pupa is scarlet and the larval skin is very thin, colorless, and transparent.

Hundreds of prenymphal pupae were examined and found to vary considerably in size. Pupae whose larvae were permitted to remain on their host and engorge themselves as long as they desired naturally were much larger than those whose larvae were removed after they had fed only a few days. Most of the pupae whose larvae were permitted to remain upon their host as

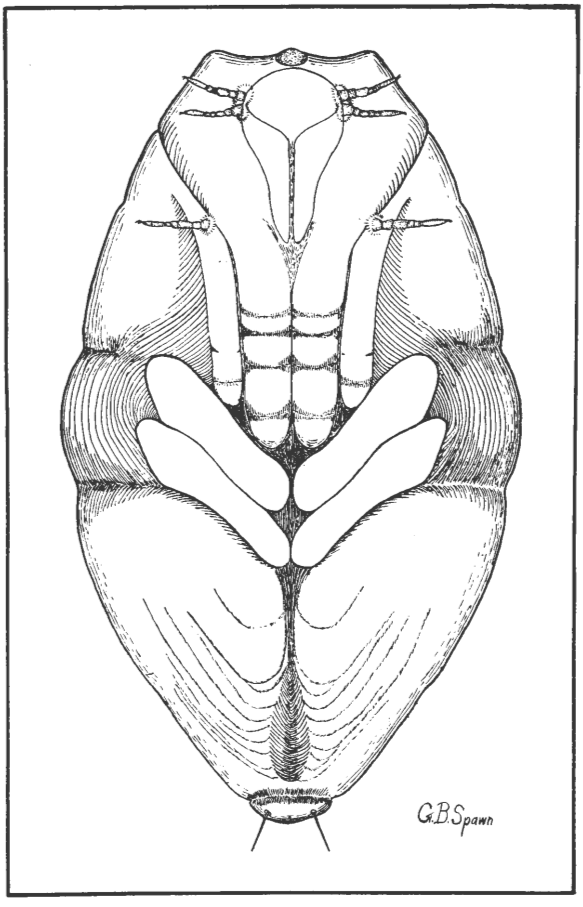


Fig. 16. Prenymphal pupa, ventral view

long as they desired measured about 2 mm. in length and 1 mm. in width. An occasional specimen of pupa was slightly larger and measured 2.2 mm. in length and 1.2 mm. in width. At the other extreme, small pupae were obtained that measured only 0.7 mm. in length and 0.4 mm. in width. These small pupae, however, had fed as larvae for only 2 or 3 days at the most. All gradations in size of prenymphal pupae between the smallest and largest may be found in any field where the mites are present.

Length of Prenymphal Pupal Period

The duration of the prenymphal pupal period varies considerably. Some of this variation is caused by differences in the prevailing temperature, while some is undoubtedly due to the amount of moisture present in the soil.

During warm weather in July and August the average prenymphal pupal period was 9 to 10 days, but some pupae gave rise to nymphs in 7 days, while others required as many as 18 days. If the duration of the prepupal and pupal periods are added, then the combined periods will require 10 to 13 days as the minimum and 18 to 20 days as the maximum with an average of about 15 days.

Seasonal Abundance

Mites in the prenymphal pupal stage make their appearance from 10 to 20 days later in the year than do the larvae. The bulk of them, therefore, occur during July, August, and September. However, prenymphal pupae may be found from late June well into October (Fig. 2).

NYMPH OF GRASSHOPPER MITE

Emergence of Nymph from Prenymphal Pupa

A larva that has engorged itself by feeding on a grasshopper drops from its host, usually burrows into the soil to a depth of ½ inch to 4 inches or more, molts, and becomes a nymph. Occasionally, instead of burrowing into the soil, a larva may crawl or burrow underneath objects or materials lying on the ground and molt.

The larval skin that is to be shed is very thin, colorless, and transparent. As the prenymphal pupa becomes older, the cuticula of the larva loosens and tends to dry. This gives the cuticula a dry, shiny appearance, but since the cuticula is transparent, the scarlet-colored nymph is readily visible through it.

If the pupa is in dry soil or is permitted to dry on the surface of the soil, the cuticula shrinks and several rents appear in it. Most of the breaks in the cuticula occur immediately outside of the legs and adjacent to them. A tear may also occur along the mid-ventral line of the body posteriorly from the last pair of legs. Through the rents made, the legs of the nymph are liberated first, the second and third pairs being the first to emerge. The cephalothorax is usually the last portion of the body to shed its skin.

If, however, the pupa is in damp soil or if it is kept moist, then the splitting of the cuticula and emergence from it is somewhat different. Usually a rent is torn in the cuticula along the mid-dorsal line beginning posterior to the anterior dorsal plate and proceeding posteriorly. Occasionally this rent occurs to one side of the mid-dorsal line. Through the rent made, the mite works out its body and legs from the cuticula, the posterior end of the abdomen being usually the last to emerge. At times the anterior end of the cephalothorax is the last portion of the body to emerge.

The cast skin is left intact where it was shed. Usually the nymph rests for a time after molting but it is capable of walking and running immediately after it has shed its cuticula.

Description of Nymph Before Feeding

In this description only such characters of the nymphs are discussed as are different from those of the adult mites described on pages 8-10. The nymphs resemble the adults closely in color and structure but differ from them chiefly in size and somewhat in shape. The larger nymphs are 1.5 to 2 mm. long and 0.75 to 1 mm. wide. The smallest nymph that was reared was 0.7 mm. long and 0.4 mm. wide. The majority of the nymphs reared measured about 1.3 mm. long and 0.8 mm. wide.

The size of a nymph that has recently emerged from the prenymphal pupa and has not as yet fed is largely dependent upon the length of time that it fed as a larva on its grasshopper host. If the larva fed for only 2 days, the nymph is small, but if it engorged itself for 8 to 14 days, the nymph is correspondingly larger.

The abdomen of a nymph is somewhat more pointed posteriorly than is the abdomen of an adult mite, while the cephalothorax is wider in proportion to the length of the body.

The palps of the nymph are similar in structure to those of the adults except as noted here. On the outer surface of segment four of the palps near the lower edge are two conspicuous heavy spines (Fig. 17, A). These spines in the adults number two to four, with three being the usual number. On the inner face of segment four of the palps of the nymphs are four or five heavy

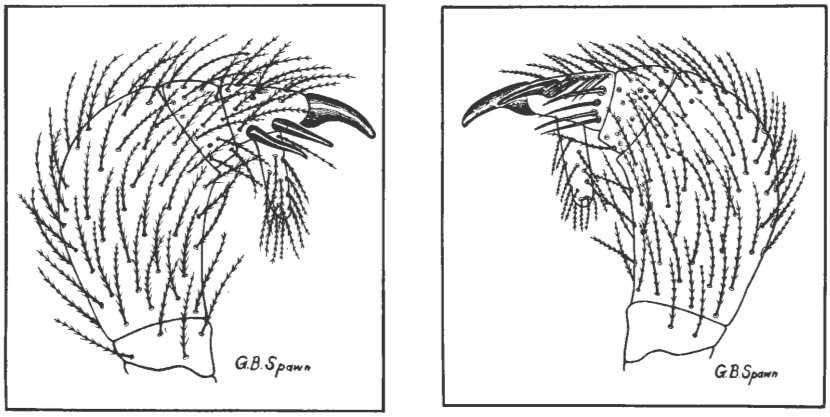


Fig. 17. (A) Palp of nymph, outer surface (B) Palp of nymph, inner surface

spines arranged in one or two irregular rows (Fig. 17, B). A dorsal comb of six to eight spines is found along the dorsal edge of the inner face of segment four. The spines composing the comb are not so heavy or so long as the four or five spines found on the face lower down.

The genital opening is closed in both female and male nymphs.

Duration of Nymphal Stage

The duration of the nymphal stage is highly variable, much more than the larval stage. With 110 nymphs reared in the laboratory, the duration of the nymphal stage varied from 13 to 50 days with 27 days as the average. Howard (6) records that it requires 14 to 20 days for the nymph to engorge itself but does not state how he obtained his data, nor is his paper clear or definite as to the duration of the entire nymphal period.

Seasonal Abundance

Mites in the nymphal stage appear in South Dakota in largest numbers from July 15 to September 30. However, since some of the nymphs hibernate, the mite may be found in the nymphal stage during every month of the year in South Dakota (Fig. 2).

Food of Nymphal and Adult Mites

The usual food of nymphal and adult mites consists of grasshopper eggs. In the rearing work nymphal and adult mites were fed the eggs of the following species of grasshoppers: *Melanoplus femur-rubrum femur-rubrum* (DeG.), *Melanoplus mexicanus mexicanus* (Sauss.), *Melanoplus confusus* Scudder, *Melanoplus bivittatus* (Say) and *Melanoplus differentialis* (Thos.). The eggs varied in age from those recently laid to those containing fairly well developed grasshopper embryos. The nymphal and adult mites fed upon all of the eggs offered them and seemed to do equally well on the eggs of the different species.

The mites were also offered small earthworms and pieces of earthworms as food, grasshoppers that had recently emerged from the egg shell, and eggs taken out of the ovaries of grasshoppers. On all of these foods the mites fed readily. Cow dung and horse dung were also offered the mites and they engorged themselves on this material. However, the dung contained small fly larvae and mites other than *Eutrombidium trigonum* (Hermann) and it is possible that the grasshopper mites obtained their nourishment from these sources rather than from the dung itself. Grasshopper mites are frequently found in the nymphal and adult stages in

and under cow and horse dung in the field. Evidently the mites find not only a favorable resting place in such material but also are able to obtain nourishment from it.

Mites in their nymphal and adult stages pass through the anus a milky-white fluid which forms a chalky-white residue when it is drying.

Technique of Feeding and Rearing Nymphs

Pieces of glass tubing 40 mm. long, having a bore of 6 mm. and annealed at both ends in the flame of a Bunsen burner, were used in which to feed and rear the nymphal mites. The open ends of the tubes were plugged with absorbent cotton which was kept damp but not wet. One nymphal mite and three grasshopper eggs of *Melanoplus bivittatus* (Say) were placed in each tube. Each tube was numbered with a China marking pencil and then placed in a 1- or 2-ounce salve box. The salve box contained a block of damp plaster of paris for additional moisture. The salve boxes were also numbered, both box and cover being numbered to avoid errors.

The contents of each glass tube were examined each morning with a binocular microscope to determine whether the mites had fed. Eggs that had been fed upon were usually more or less collapsed, more collapsed when a considerable amount of the egg contents had been removed by the mite. However, when the total quantity of material removed from the egg was small, the chorion and vitelline membrane collapsed but slightly or not at all. The degree of collapse evidently depends upon the total quantity of fluid removed from the egg, and this quantity in turn may depend upon the length of time and the number of times the mite fed, the size of the mite, and the size of the egg.

A more reliable method of determining whether an egg had been fed upon was to examine each egg carefully for feeding punctures. Such punctures are made by the chelicerae of the mite and consist of two minute holes in the chorion of the egg. The holes are located in a circular area which soon turns brown or pink.

A nymph that is about to feed examines an egg carefully before sinking its chelicerae through the chorion and vitelline membrane. After the chelicerae have been forced into the egg, the mite begins to suck out the fluid contents. The number of eggs that an average mite will feed upon during its nymphal existence and the damage that it does varies so much that it is impossible to state how many eggs will be destroyed by it during this stage of its existence.

There is much variation regarding the time when the first meal is taken by the mites during their nymphal existence, the last meal, and the time intervals between meals. Further, there is much variation between mites as to the total quantity of food taken. From careful observations made on 25 nymphs, the following facts were learned: mites may or may not feed during the first day of their existence and for several successive days; they may feed on the day previous to the time that they prepare to pupate; and they collapse 1 to 14 grasshopper eggs in varying amounts during their entire feeding period.

A peculiar phenomenon was observed in connection with grasshopper eggs that had been partially collapsed because of the feeding activities of nymphal mites. When such eggs were taken out of the glass feeding tubes and exposed to the drying influence of the atmosphere, they rounded out within a few seconds or minutes and would then look very much like normal eggs except for the feeding spots upon their chorion. When such eggs were placed upon damp soil or a damp block of plaster of paris, they collapsed again. This process could be repeated in-

definitely. This phenomenon was not due to the action of the chorion, for it took place even though the chorion was removed from the eggs. It must be taken into consideration in a study of certain feeding habits of the mites.

Ability of Grasshopper Eggs Used as Food to Hatch

Recently laid grasshopper eggs of *Melanoplus mexicanus mexicanus* (Sauss.) were offered as food to nymphal and adult mites. The mites fed upon these eggs and the chorion and vitelline membrane of the eggs promptly collapsed. The degree to which the chorion and vitelline membrane collapsed varied, depending upon the amount of fluid that had been extracted from the egg by the feeding mite. The eggs were then placed on damp blocks of plaster of paris and these blocks were put in salve boxes. The eggs from which much of the fluid had been removed remained collapsed and died. However, the eggs from which considerably less than half of the fluid had been removed regained their plump appearance within 72 hours. These eggs ultimately developed embryos and gave rise to young hoppers which apparently were normal in all respects.

Eggs that were laid by *Melanoplus mexicanus mexicanus* (Sauss.) and that had young embryos within them were also offered as food to the mites. The mites fed upon these eggs and the eggs collapsed like those already discussed. Such eggs which were slightly collapsed regained their normal plump appearance when placed on a damp block of plaster of paris and ultimately gave rise to young hoppers. However, when much of their fluid contents had been removed by the mites, the eggs remained collapsed and died.

Transformation of Active Engorged Nymph Into Inactive Engorged Nymph

After a nymph has engorged itself with food, it leaves the food and either comes to the surface of the ground or burrows into the soil surrounding the food. If it comes to the surface of the ground, it may wander about for some time but ultimately burrows into the soil to a depth of 1 to 4½ inches, hollows out a small chamber, and inside this chamber prepares to pupate. If the nymph does not come to the surface of the ground, it may hollow out its chamber close to the food upon which it fed or burrow into the surrounding soil for several inches or more and then construct its chamber. Occasionally nymphs were found that had pupated under objects or materials lying on the ground, such as boards or cow dung.

Previous to pupating, the active engorged nymph becomes an inactive engorged nymph. From 1 to 5 days are required for this transformation. During transformation the body of the nymph becomes more and more rounded, the dorsal surface more rounded than the ventral. The integument stretches and the constrictions in the body are eliminated. The integument becomes shiny and the hairs, especially on the dorsal surface of the body, become separated, thus exposing the cuticula. All powers of locomotion are ultimately lost, and finally it becomes impossible for the mite to move even the distal ends of the legs or palps. The first pair of legs are extended straight forward and are held close to the palps (Fig. 18). The second pair of legs are extended forward and somewhat laterally. The third pair of legs are extended lateroposteriorly while the fourth pair are extended mainly posteriorly and only slightly laterally. While the legs are now incapable of movement, they are still flexible.

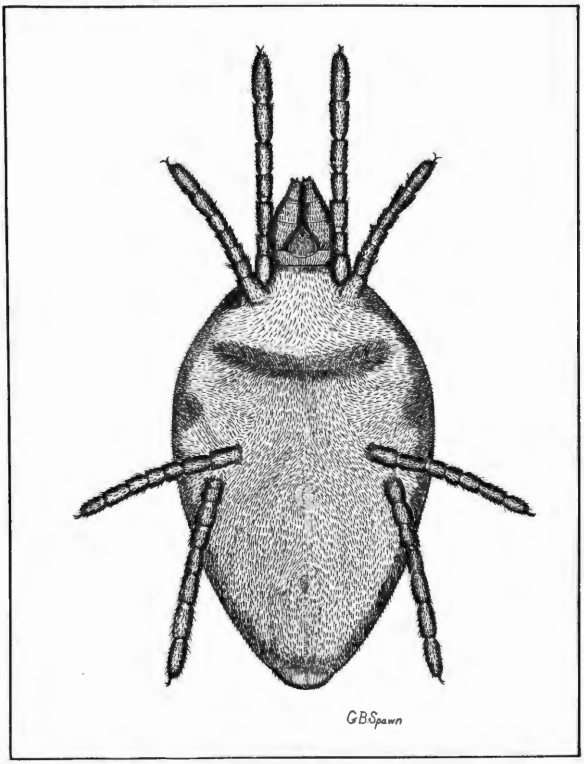


Fig. 18. Inactive engorged nymph about to pupate

Specimens in this stage of development vary much in size. The following measurements of length and width of body of 20 specimens shows the range in variations:

Length of body exclusive of legs or palps	Width of body	Length of body exclusive of legs or palps	Width of body
mm.	*mm.*	*mm.*	*mm.*
3.4	1.8	2.5	1.5
3.2	1.8	2.5	1.4
3.0	1.8	2.4	1.3
3.0	1.5	2.3	1.3
2.9	1.7	2.3	1.2
2.9	1.4	2.1	1.0
2.8	1.7	1.8	1.1
2.8	1.6	1.7	1.2
2.7	1.7	1.5	1.9
2.6	1.5		

Average body length, 2.4 mm. Average body width, 1.4 mm.

PREIMAGINAL PUPA

Actual pupation takes place within the nymphal cuticula. The cuticula is gradually worked loose. As this progresses, the body color changes to a scarlet tinged with yellow because the loosened cuticula is a transparent yellow and the pupa beneath is scarlet.

Description

The newly formed preimaginal pupa is slightly smaller than the engorged nymph and is formed inside of the cuticla of the nymph (Fig. 19). The legs and palps of the pupa, at first difficult to make out, gradually become more and more plainly visible. These appendages, while free from the body, are folded against the ventral surface of the body.

The distal ends of the posterior two pairs of legs of the pupae are located between the widely separated last two pairs of legs of the nymph, and the entire first two pairs of pupal legs are located posterior to the first two pair of legs of the nymph. The bases of the palps of the pupa occupy a small space between the bases of the first and second pair of legs of the nymph.

As the pupa becomes older, the nymphal cuticula dries and shrinks. That portion of the

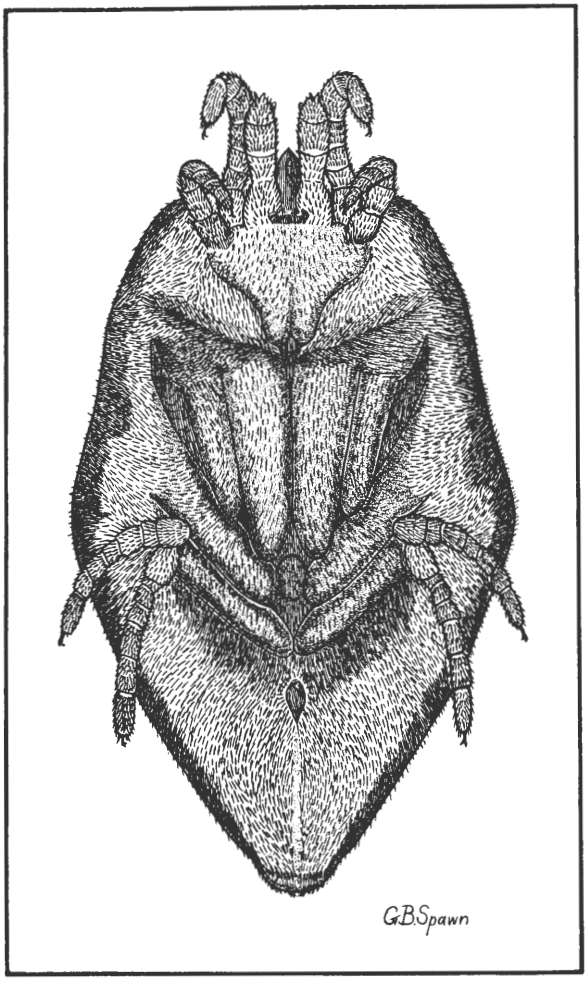


Fig. 19. Preimaginal pupa

nymphal cuticula which covers the body of the pupa seems to become thinner, but this does not seem to be true of the cuticula which covers the legs, mouth-parts, and cephalothorax of the nymph. Shortly after pupation begins, the nymphal legs begin to curl so that ultimately the curled legs are situated beneath or alongside the body. The spot in the nymphal cuticula where the genital opening will appear in the adult is very conspicuous at this time, as is also the anal opening.

Period as Inactive Engorged Nymph and Prenymphal Pupa

The length of time that a mite spent as an inactive engorged nymph varied from 1 to 5 days. Under laboratory conditions, checked by field work, the preimaginal pupal period varied from 9 to 18 days with an average of 12.3 days. These figures are based upon data obtained from 110 specimens that were reared through their entire life cycle. The combined periods varied from 10 to 23 days with an average of 14.7 days.

Seasonal Abundance

The bulk of the mites in the preimaginal pupal stage are to be found from late in July to September 30 though smaller numbers occur during June, the first half of July, and during October (Fig. 2).

ADULT MITES

Emergence from Preimaginal Pupa

Details of emergence of the adult mite from the preimaginal pupa vary considerably, depending largely upon the amount of moisture in the soil. As the pupa becomes older, the nymphal cuticula covering the body of the adult mites is loosened. If the cuticula is permitted to dry, it cracks and tears in many areas over the body, but chiefly over the legs and mouth-parts of the adult and adjacent to them. As the cuticula dries more and more, it acquires a dry shiny appearance, and since it is colorless, the scarlet color of the adult becomes readily visible through it. At the same time, the posterior dorsal plate of the nymphal cuticula becomes loosened and takes on a conspicuous yellow appearance.

If the preimaginal pupa is kept moist, however, the cuticula does not dry nor does it crack and tear in haphazard method, but a rent is torn in it on the dorsum of the abdomen extending from the anterior end to the posterior dorsal plate. The rent does not always occur along the median line of the body. Through the rent made, the adult mite works out its body, the posterior end of the body being the last to emerge.

Immediately after emerging, the adult mites are capable of walking and running but usually they remain for some time in the chamber where the transformation took place.

Seasonal Abundance

Adult mites are to be found throughout the year (Fig. 2). During the late fall and throughout the winter very few adults are to be seen on the surface of the soil. But during the spring, the mites often come to the surface of the soil in large numbers to sun and warm themselves and to search for food. Naturally, there may be considerable variability in time when the adult mites make their appearance in the spring on the surface of the soil, not only in different areas of the state but also in the same area, and even in different portions of the same farm. This variability is largely, if not entirely, due to the fact that for many reasons the soil in different portions of a farm does not warm up to the same temperature at the same time. Further, seasons vary, often to such an extent that there may be a sufficient amount of warm weather in March to bring out large numbers of the mites but during a later spring the adult mites may not appear in large numbers until April.

Abundance of Nymphal and Adult Mites in or on Soil

During the outbreak of the rocky-mountain locust in 1877, Riley (8) reported that the grasshopper mite sometimes became so abundant "as to give the ground a scarlet hue." C. W. Howard (6) reported that in grasshopper areas in Minnesota the mites "may be so numerous in ordinary years that several hundred can be collected in three or four hours."

In South Dakota the mites were not so abundant as described by Riley even in the worst grasshopper years or in the most heavily infested areas. But they are more abundant than described by Howard for Minnesota.

In certain areas in South Dakota that were heavily infested with grasshoppers during several successive years the mites average 5 to 10 per square foot on the surface of the ground during the first warm days of spring. In other areas as the soil became dry the mites sometimes concentrated on the damper spots during hot days and at such times it was not unusual to count as high as 45 to 50 mites per square foot of surface. This count of course does not take into consideration the mites that were out of sight beneath the surface of the soil.

Number of Mites Found Within Grasshopper Egg Pods

Usually only one nymphal or adult grasshopper mite is found within a grasshopper-egg pod but there are frequently two and occasionally three or more. When two or more adult mites were found within a pod, very frequently there was but one female mite in the pod, while the remainder of the mites were males.

DEATH FEIGNING

The grasshopper mite can feign death in any of its active stages—the unengorged and engorged larval, nymphal, and adult stages. A jar or touch may throw it into the death feint. When it feigns death, the forelegs are directed forward and curled underneath the body, while the posterior pairs of legs are curled to the side and underneath the body.

Mites that are in the engorged larval stage, or in the engorged or unengorged nymphal or adult stages, pull the cephalothorax back into the abdomen when they pass into the death feint. They remain in this feint usually from a few seconds to several minutes. It is possible to throw the mites into the feint time and again through the proper stimulus but finally they no longer react.

SUMMARY

The grasshopper mite, *Eutrombidium trigonum* (Hermann), is an important enemy of grasshoppers in South Dakota. In its larval stage it is parasitic on grasshoppers and in its nymphal and adult stages, it is predaceous on the eggs of grasshoppers.

A study of the life cycle of the mite has shown that it has one complete generation and a partial second generation a year in South Dakota. It may pass the winter in the soil as an adult mite or as a nymph. The eggs of the mite are usually laid in small chambers in the soil, the average number laid by a single female being about 4,700. Egg laying may be continued over several weeks and several egg masses may be laid by a single female. Within 2 to 4 weeks the eggs usually hatch into six-legged larval mites.

The larval mites are external parasites of adult and nymphal grasshoppers. All species and varieties of grasshoppers that occur in South Dakota are subject to

attack by these mites. The larval mites remain attached to the body or to the appendages of a grasshopper for 8 to 14 days, if possible, and during this time they engorge themselves with the blood of the host. They then drop from the host, burrow into the soil, and pupate.

The mites remain in the prenymphal pupal stage for 7 to 18 days and then emerge as eight-legged nymphs. The duration of the nonhibernating nymphal stage averages about 27 days. During the nymphal stage, the mites prefer to feed upon grasshopper eggs, whose liquid contents the mites suck out through their mouth-parts. Towards the end of the nymphal stage, the mites burrow into the soil and transform into preimaginal pupae.

About 2 weeks are spent as preimaginal pupae and then the mites emerge as adults. The preferred food of the adults consists of the liquid contents of grasshopper eggs. Under favorable conditions the entire life cycle of a grasshopper mite may be completed in 61 days.

The larval mites have little direct effect upon the health of the infested grasshoppers except to weaken them a trifle. They do not prevent nymphal grasshoppers from maturing and developing into apparently normal adults. Even though the mites may be fastened to the wing pads of nymphal grasshoppers, such pads are not seriously damaged, for when the nymphs ultimately become adult grasshoppers, the wings seem to be normal in every way.

When an adult grasshopper becomes heavily infested with larval mites, the majority of the mites are attached to the hind wings and to the dorsum of the mesothorax and metathorax. When such mites become large, they may prevent the grasshopper from folding the wings properly. As a consequence, the tegmina and second pair of wings become much battered and broken, at times so badly as to be reduced to mere stubs. A severe infestation of mites upon the wings and at the base of the wings of grasshoppers may interfere seriously with efficient flight. A moderate infestation of adult grasshoppers does not seem to shorten the life of the insect materially nor does it seem to interfere with normal reproduction.

Both the nymphal and adult grasshopper mites prefer to feed upon the liquid contents of grasshopper eggs. Eggs drained of their liquid contents so that the chorion is severely collapsed usually die, while eggs that are not so seriously damaged recover. A nymphal mite may collapse 1 to 14 grasshopper eggs, but only a fraction of these eggs are actually destroyed. An average adult female mite in its preoviposition period consumes the entire or only a portion of the liquid contents of 3 to 4 grasshopper eggs and may collapse 2 to 16 additional eggs during the remainder of its life. However, not all of these eggs are actually destroyed. Those that are not will give rise to apparently normal grasshopper nymphs.

Grasshopper mites have been so abundant during some years in some sections of the United States as to actually control a severe outbreak of grasshoppers. Such conditions have not been observed in South Dakota. However, the red mite is consistently present in all sections of the State each year, and during years favorable to it, is one of the important checks on grasshoppers.

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